Status of the design of triplet BPMs

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HL-LHC WP2– 23rd May 2014

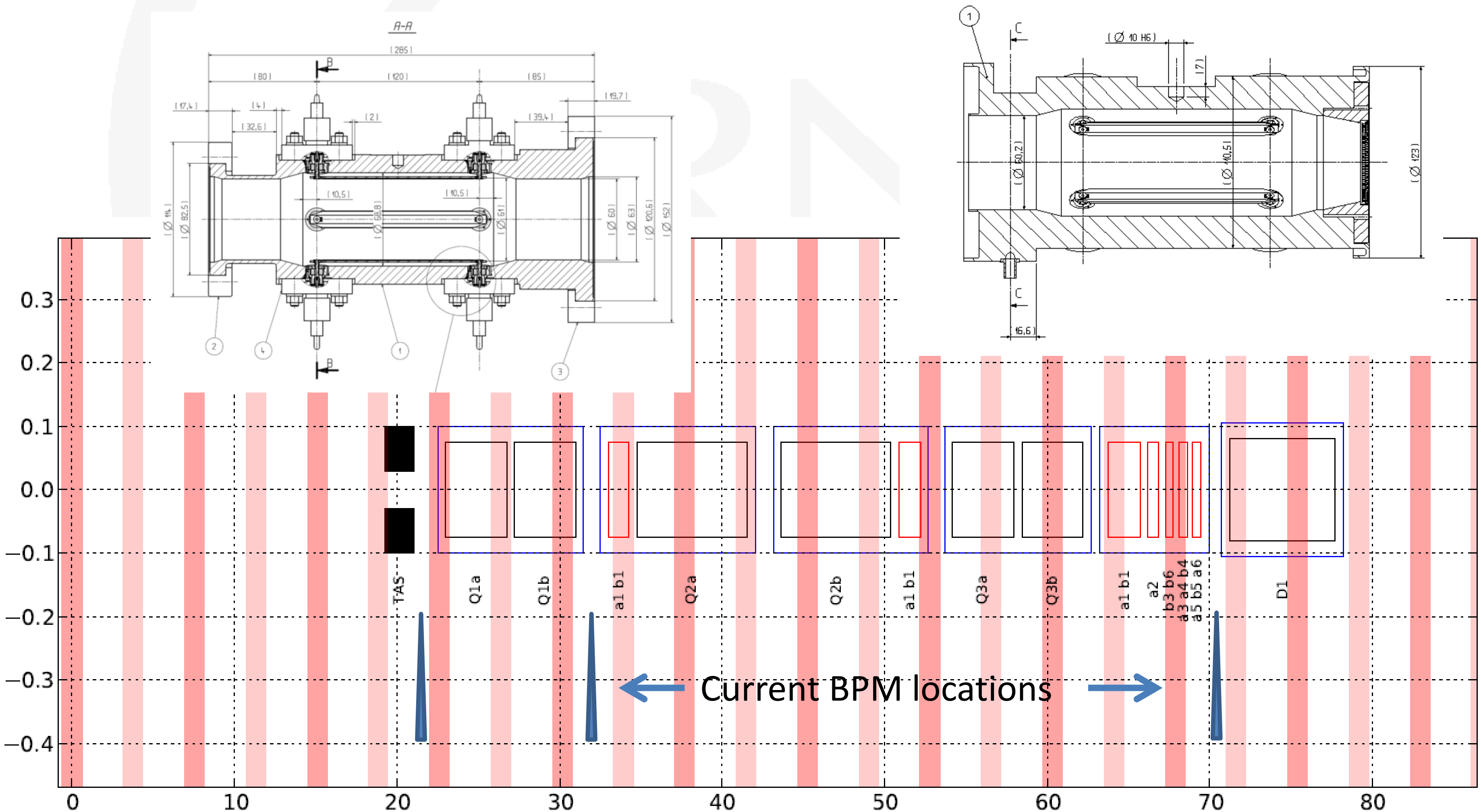
Outline

- **Status of the current LHC triplet BPMs**
  - Current performance and known limitations
  - Post LS1 operation..
- **Design for HL-LHC**
  - Specifications and constraints
  - Pick-up design
- **Future plans, milestones & conclusions**

LHC triplet BPMs (1)

BPMSW – Warm BPM in front of Q1

BPMS – Cold BPM in Q2

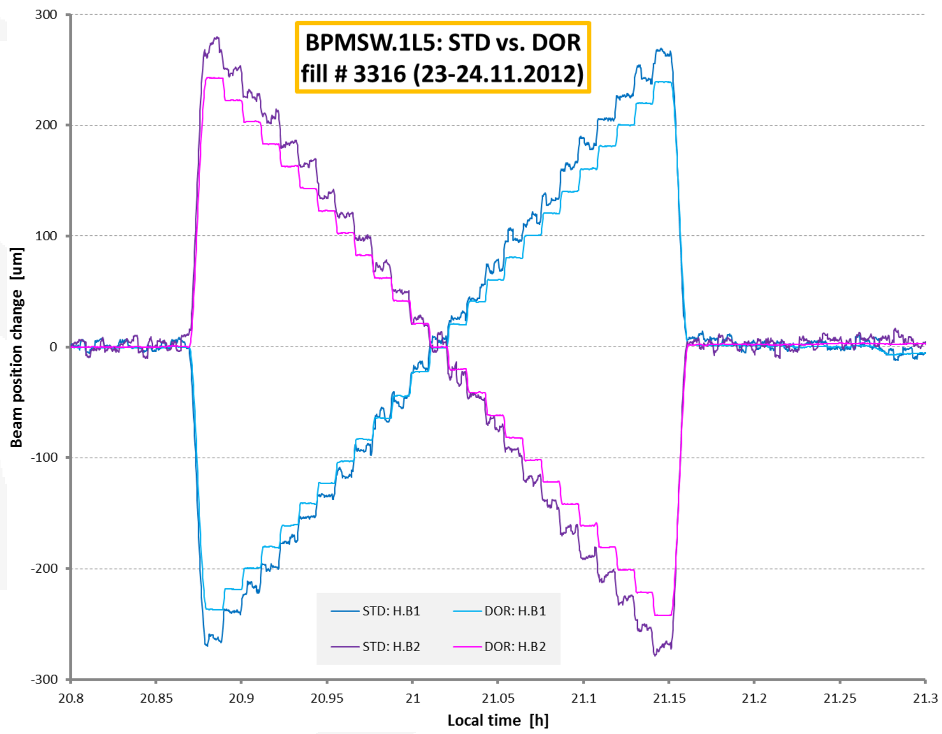


LHC triplet BPMs (3)

- **Performance and Known Limitation**
  - **Limited number of BPMs** : no redundancy..
  - **Limited Accuracy**: BPMSW @Q1 very difficult to align properly: large uncertainty of the alignment procedure : not better than 1mm
  - **Stability issue** due to Tp dependence in the acquisition system
  - **Limited directivity** of the present strip-line design: worse than 20dB full bandwidth
    - Cross-talk between the two beams
    - Error depends of the bunch intensity and position
  - Resolution of the order of **100um in B/B** and better than **10um in Orbit mode**
    - Linked to the current electronic design

Post LS1 (1)

- **Improving the cross-talk between two beams**
  - Using the **Synchronous orbit mode** which only measures non colliding bunches: Tested on one BPM in 2012 – Need to be deployed possibly on all BPMs
  - New high resolution electronic (<100nm), **DOROS, being installed in parallel to WBTN on Q1: option for gating on specific bunch**

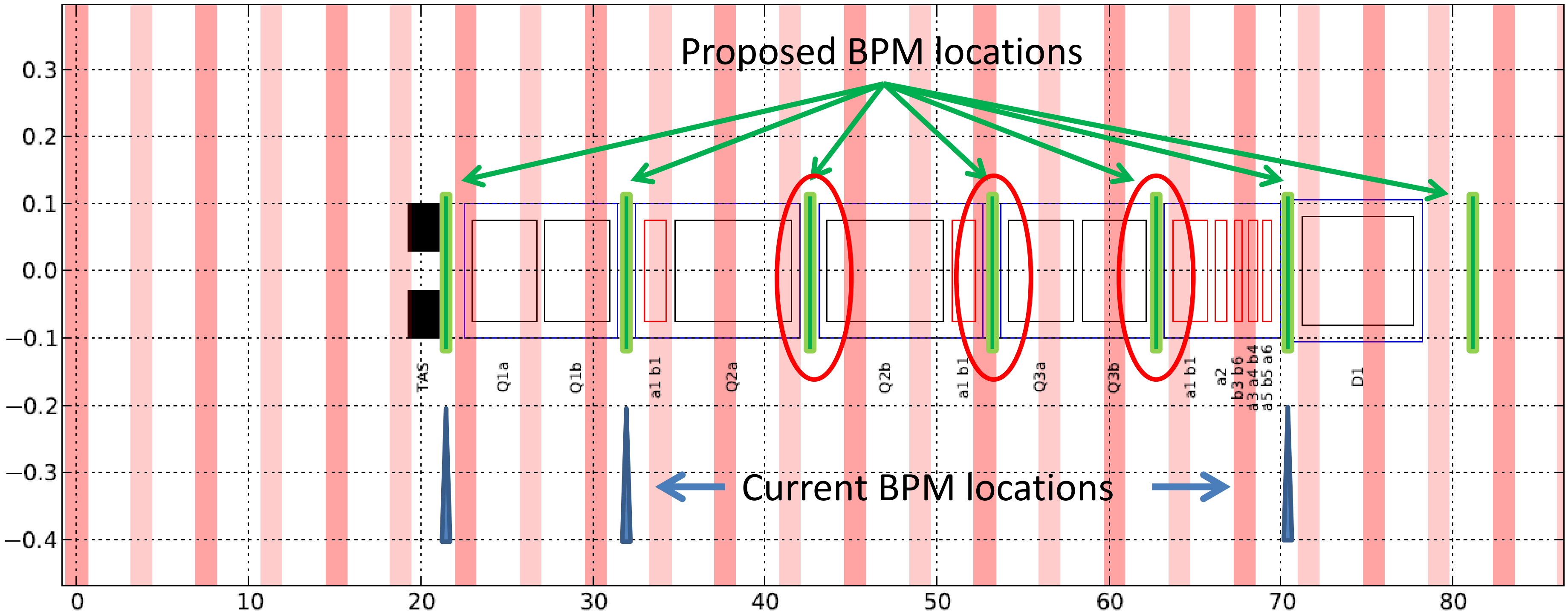


HL-LHC constrains

- **Inermet shielding for absorbing collision debris**
  - Need to rotate BPM by 45 degrees & insert shielding on mid-planes
  - Add weight, design complexity (transition from beam screen to BPM) and probably quite costly
  - Add. heat deposition that need to be estimated
- **Cryo BPM : Cold to warm implies using sliding contact for strip-line**
- **Larger aperture**
  - less signal & lower final resolution
- **Heat deposition from pick-up (<100mW)**
  - The static heat load for the BPM cables was estimated in 2003 to be 58 mW per cable for a 1.25m cable going from the cold BPM at 25K to the cryostat flange. (for a 0.141” Outer jacket°)
  - The dynamic heat load added by BPM signal was estimated to 32mW/cable for Ultimate bunch intensities

HL-LHC BI proposal

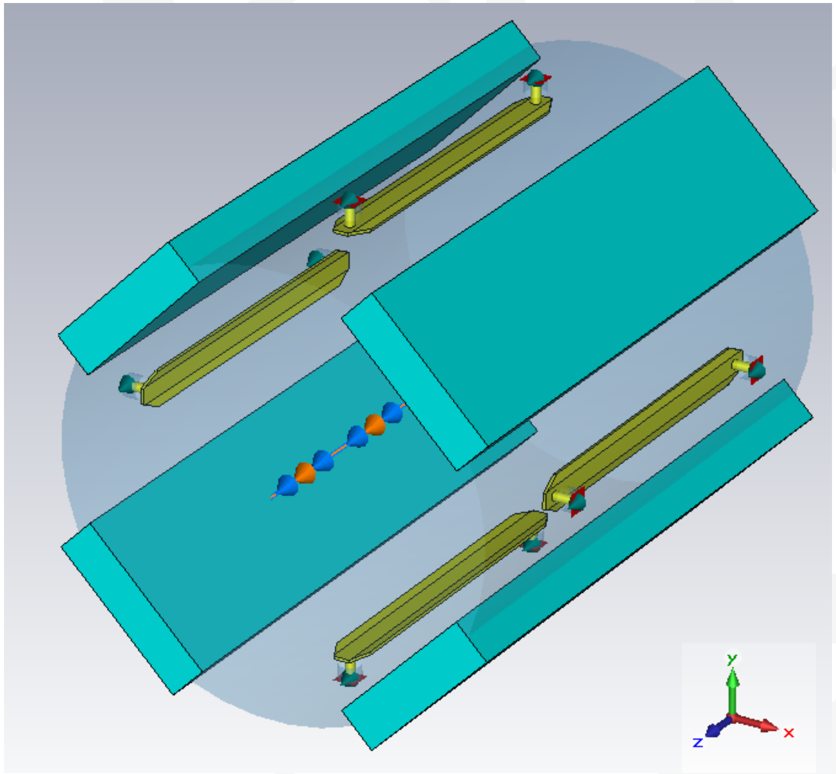
- **Proposed BPM Layout**
  - 7 monitors for better tuning and redundancy
  - Rotated by 45 degrees with Inermet shielding



BPMs located in the interconnects – Integration and alignment to be worked out carefully

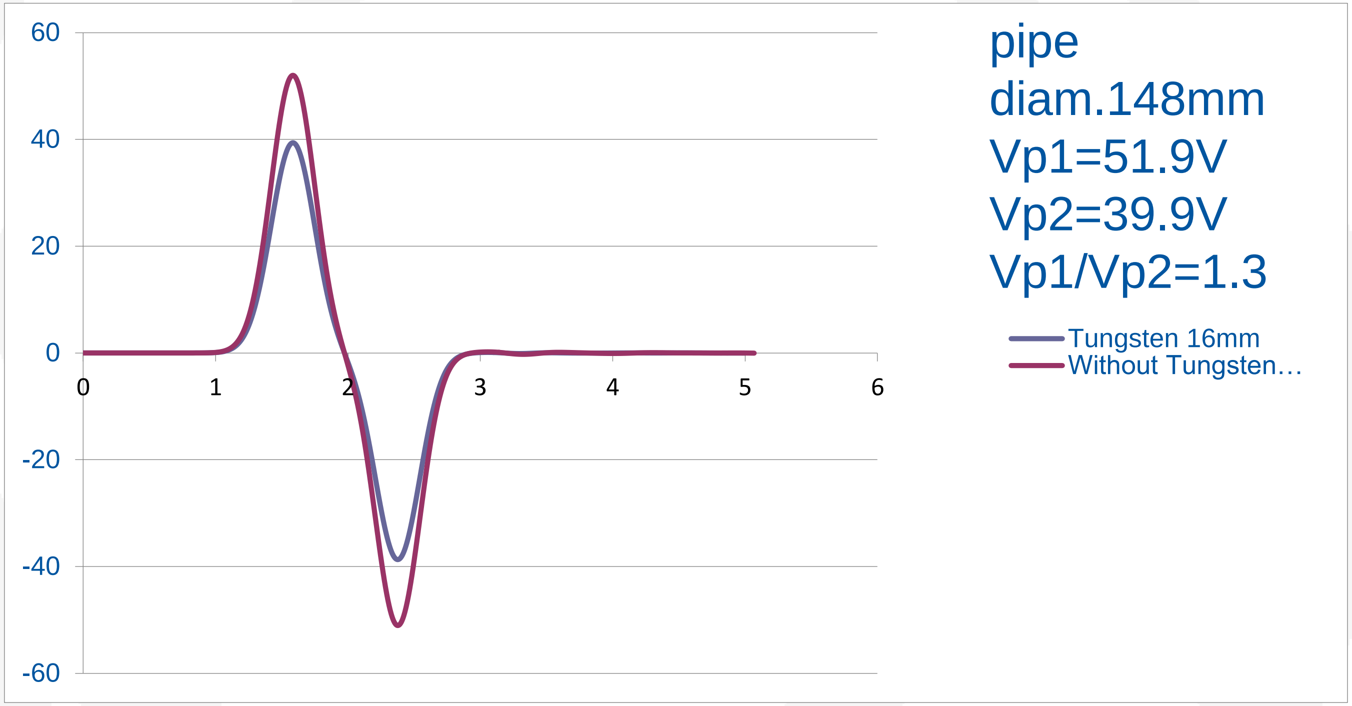
HL-LHC Strip-line design (1)

Design with standard 120mm electrode shape
fitted into a 148.8mm pipe and Added Tungsten-Inermet absorbers



- CST PS Wakefield simulations with and without Tungsten-Inermet (Electric conductivity 1.2e7 S/m), 16mm thick absorbers, small bunch (beam_sigma 50mm)
- Simulated with different pipe dimensions
- Decrease in voltage signal level (pipe diam.148mm -30%, pipe diam. 100mm -35%)
- As both Vu and Vd levels are decreasing, change in directivity is small.

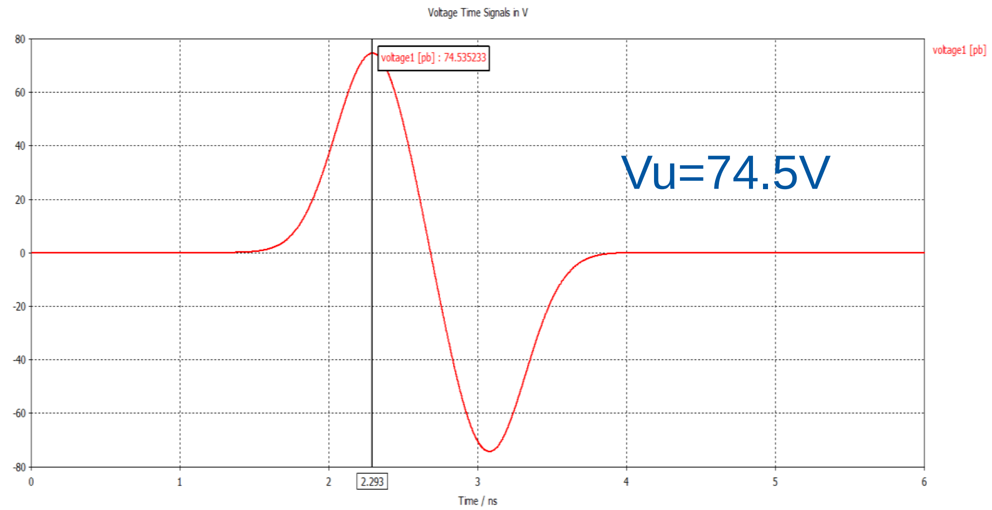
HL-LHC Strip-line design (2)

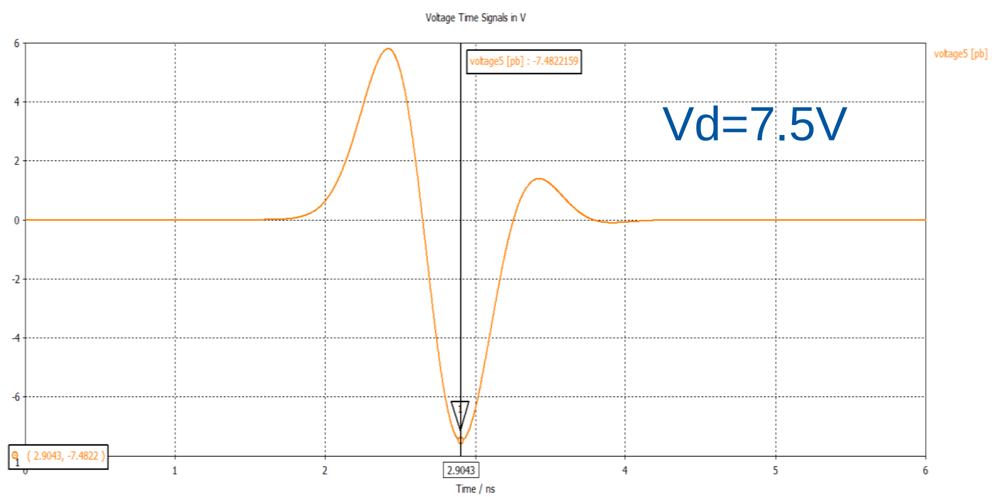


- Decrease in voltage signal level (pipe diam.148mm -30%, pipe diam. 100mm -35%)
  - Anyway voltage levels too high for existing pick-up - electronic: We have attenuators before the electronic

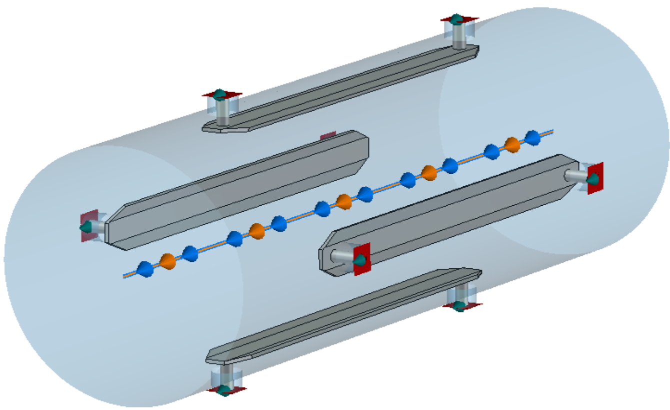
- As both Vu and Vd levels are decreasing, change in directivity is small.

HL-LHC Strip-line design (3)





'Old' BPMSW



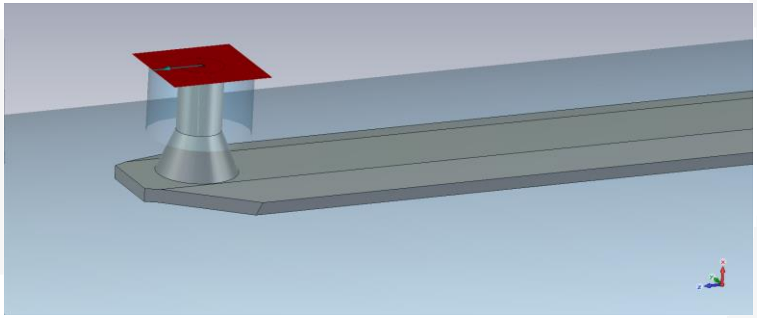
Directivity : 20dB full bandwidth

HL-LHC Strip-line design (4)

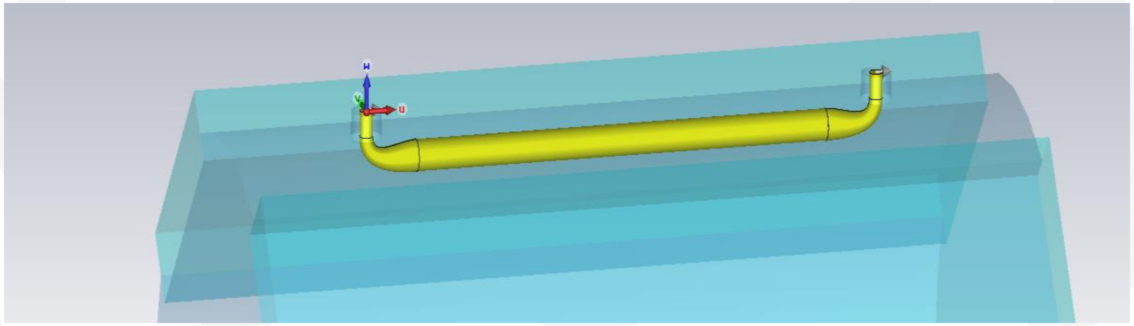
- **Maintaining the high degree of directivity requires that:**
  - The velocity of the beam and the signal be matched fairly well. For highly relativistic beams this requires a minimum amount of dielectric material in the vicinity of the stripline
  - A matching of the stripline impedance to the transmission line or termination impedance at both ends. i.e. impedance mismatch of 10% will reflect 25% of the power to the wrong port. This would limit the directivity (theoretically) to 26 dB
  - Minimization of the coupling between the striplines. If the interelectrode capacitance per unit length is too high, then one stripline can induce signals in the other

HL-LHC Strip-line design (5)

- **Currently trying different approaches:**
  - Redesign transitions (smoother, conical)

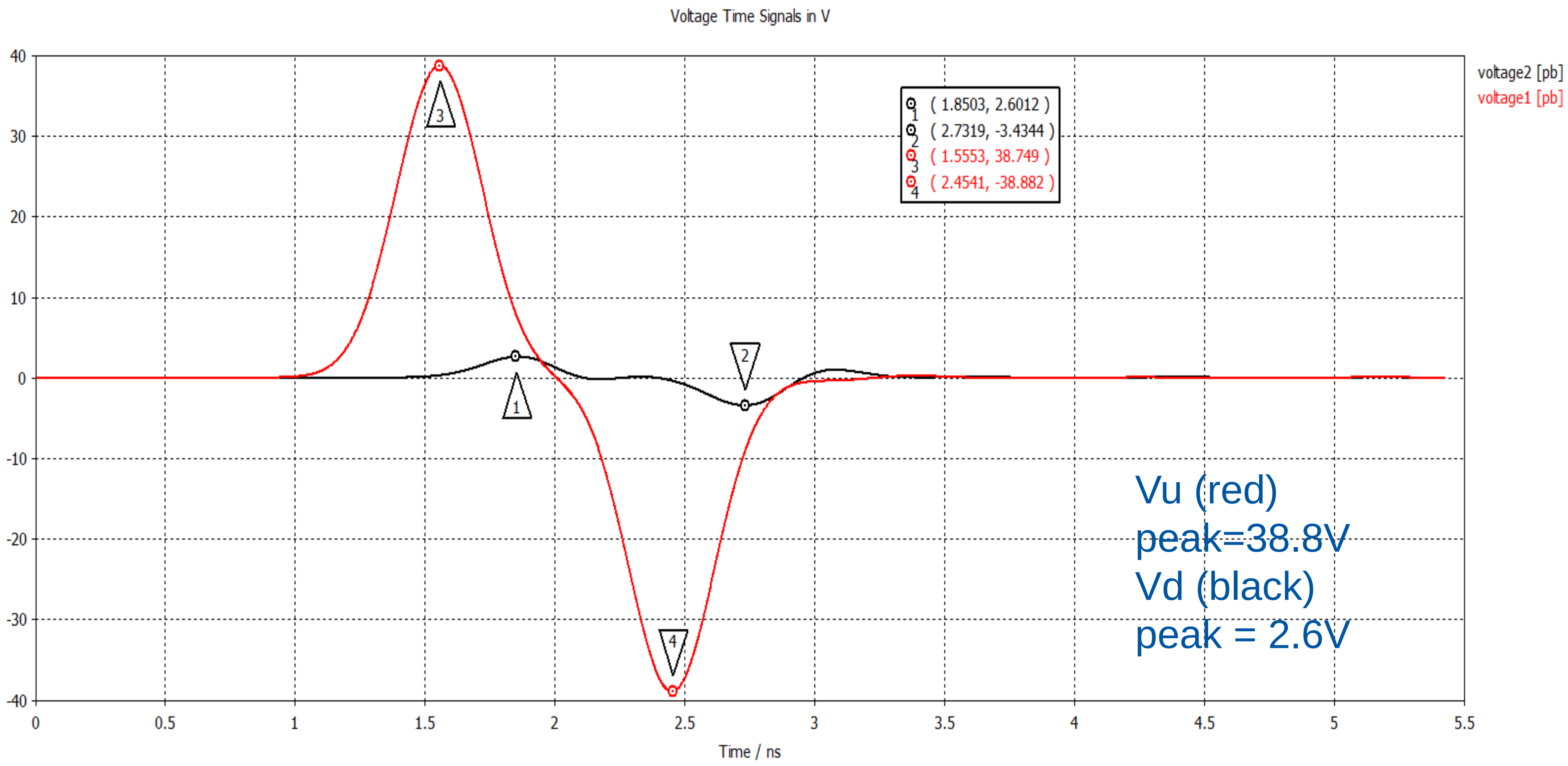


  - Redesign electrode shape (i.e;cylindrical, exponential stripline)



  - Change shape of the pipe by adding sub-cavities (the idea is to make smooth transition between the connector and the electrode by aligning them on the z-axis)

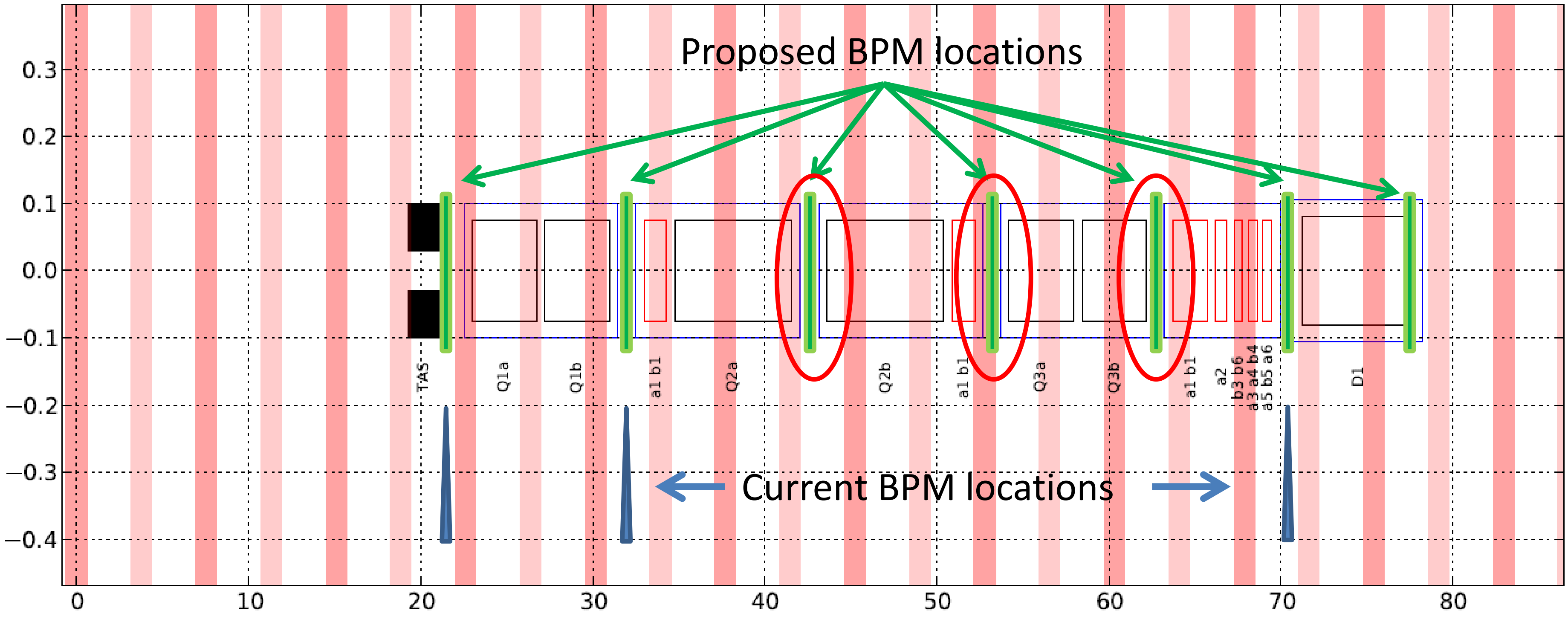
HL-LHC Strip-line design (6)



Directivity : 23.5dB

HL-LHC BPM Layout

- **Impedance and number of BPMs**
  - BPM@Q1 bad for impedance but may be crucial for beam tuning
  - Preferably sacrifying BPMs at non-optimized position where two beams overlaps
  - Keep redundancy for cold BPMs



Plans and Milestones

- Pick-up design: RF optimization completed by mid 2015
- Pick electronic: Comparison between DOROS and WBTN: End of 2015
- Pick-up Mechanical design by end 2015 – prototype design
- Electronic development: possibly other system using fast sampling – mid 2016
- Mechanical integartion in the Cryostat – end 2016
- Prototype production (Beam test) by End 2016 (2017)
- Launch production in 2018

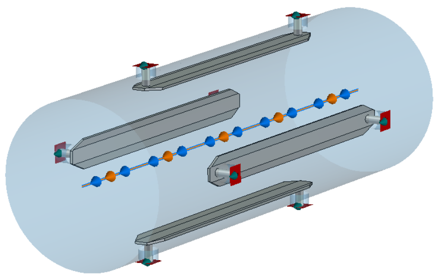
Conclusions

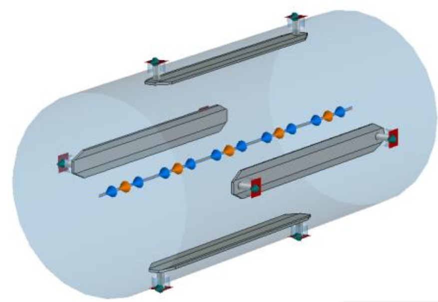
- Improved Pick-up design started
  - Aiming for higher directivity
- Electronic performance in terms of resolution to be assessed on LHC after LS1
- Converge on Engineering specifications by 2016-17 (both pick-up and electronic)
- Impedance/number of BPMs to be agreed

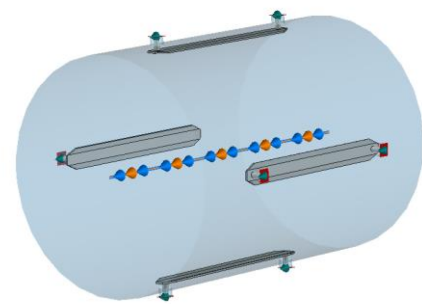
CERN

LHC triplet BPMs (2)

- ## BPM Aperture & Length
  - Aperture
    - NOT related to length
    - Can adapt the same BPM for any aperture
    - Larger aperture ⇒ less signal & lower final resolution

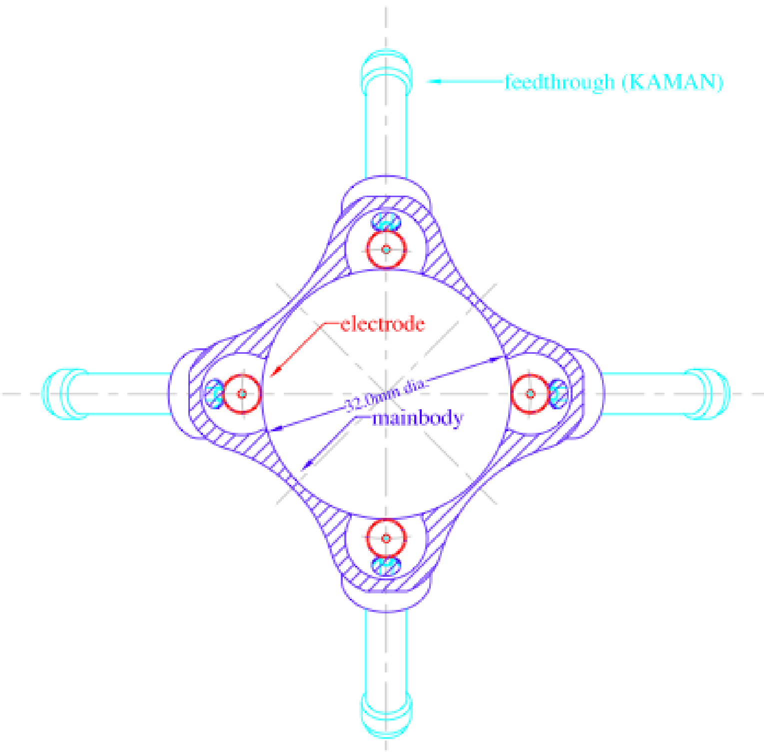


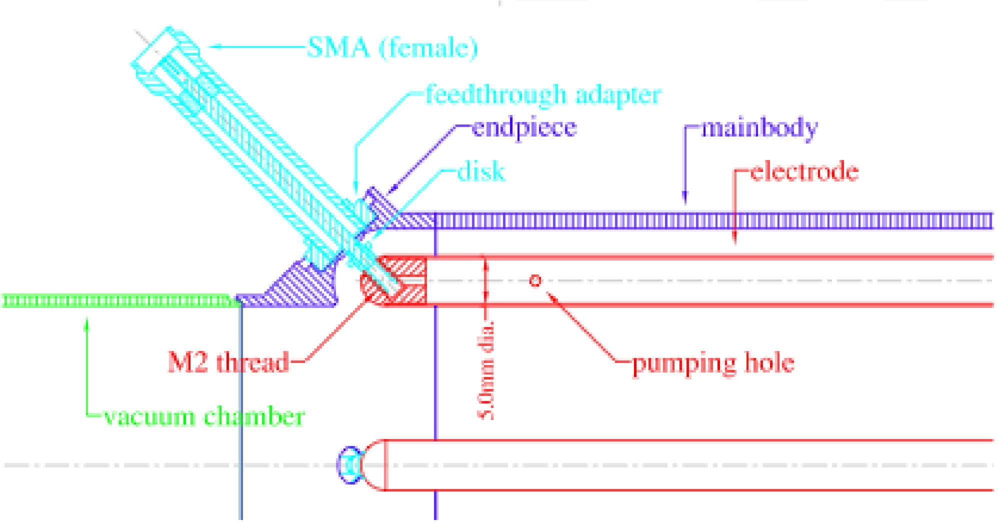




	BPMSW/S	BPMSX	BPMD/BPMSE
Beam pipe diameter (mm)	68.8	88.8	138.8
Aperture (mm)	61	81	131
Electrode length (mm)	120	120	120

TESLA DESY stripline BPM example





W.Radloff, M.Wendt, “Beam Monitors for the S-Band Test Facility”
C.Magne, M.Wendt “Beam position monitors for the TESLA accelerator complex” (2000)